



Overview for Industry

NASA R&D for Air Transportation System Innovation



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Florida Aviation Trades Association
Sarasota
June 10, 2003



Outline

- **Context for Transportation System Innovation**
- **SATS Project Status**
 - Technologies
 - Market & Business Model Assessments
- **FAA Activities**
 - Small Community Airport Initiative
 - AVR SATS
 - Pilot Training Initiative
- **Planning for 2005 SATS Demonstration**



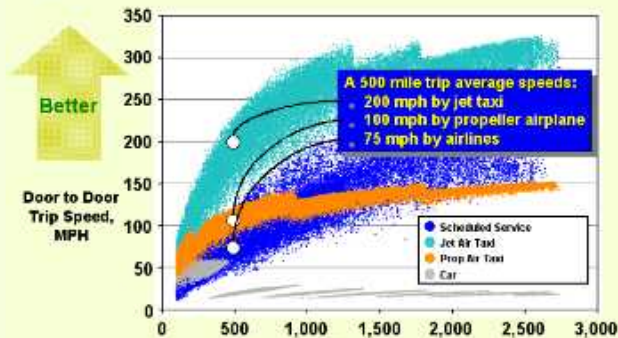
Why SATS?
Why a Public-Private Partnership?
Why Florida?



The Perfect Storm

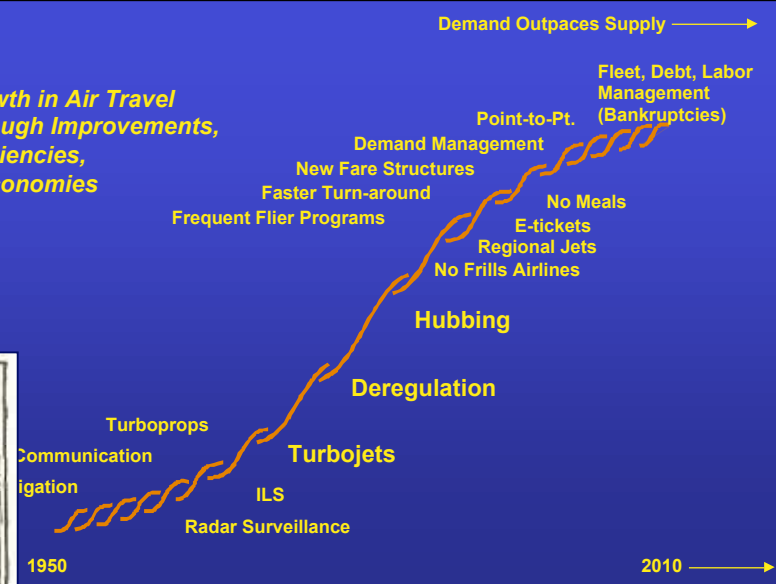


*If Time is Gold
Then Door-to-Door Speed is the Coin of the Realm*

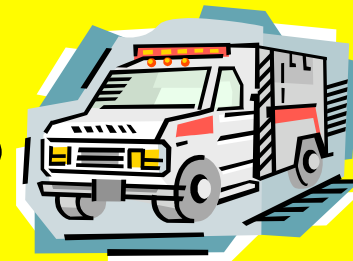


*A Notional Life Cycle
of The Hub-and-Spoke Innovation*

*Growth in Air Travel
Through Improvements,
Efficiencies,
& Economies*



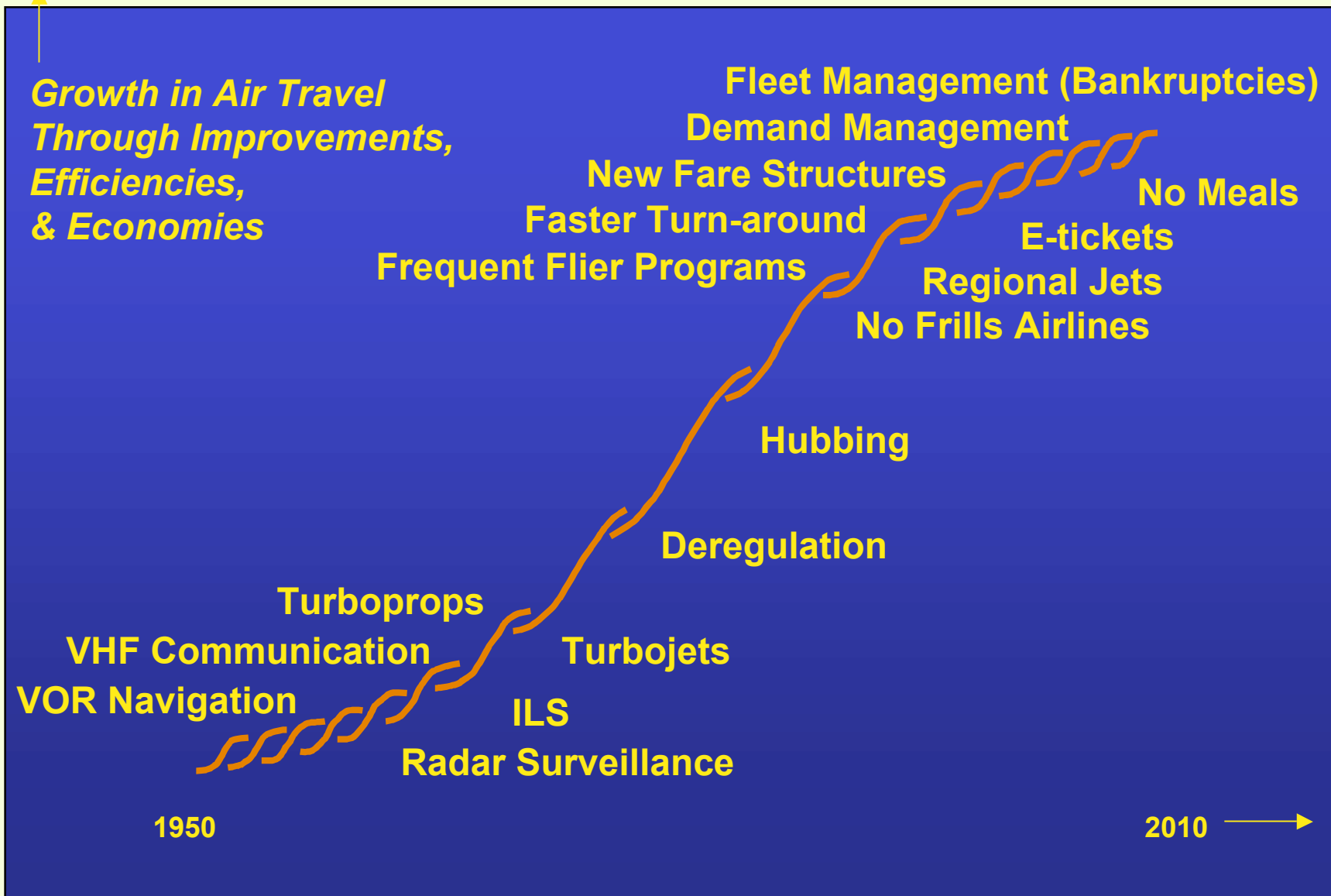
SARS



Security

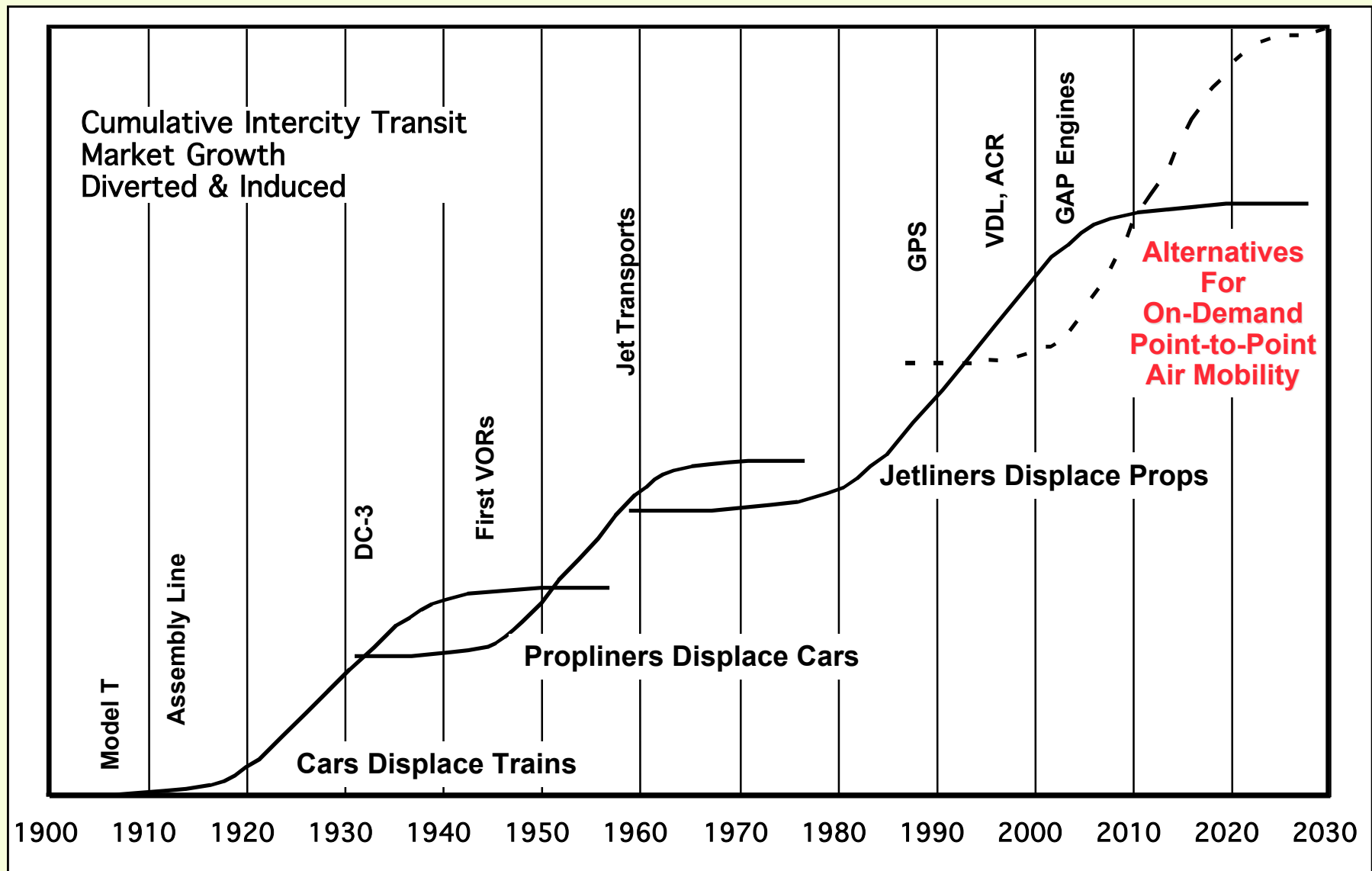


The Notional Life Cycle of The Innovation Called Airline Travel






Notional Life Cycles in Transportation





Technical Context for Mobility Alternatives

1. Moore's Law on microprocessor performance
2. Gilder's Law on bandwidth performance
3. Metcalf's Law on network performance
4. The unwritten law of abundance
5. The unwritten rule of gridlock
6. Kurzweil's Law of Accelerating Returns
7. The Golden Rule of the information age



The NASA Mission

*To understand and protect our home planet
To explore the Universe and search for life
To inspire the next generation of explorers*

... as only NASA can.

5



**Aeronautics
Blueprint**

2002 2005 2008 2011 2014 2017 2020

Revolutionary Vehicles
On-Demand Mobility
Enhanced Workplaces
National Security

**The
Aeronautics
Blueprint**

- A National Imperative -

■ The cost of inaction is gridlock, constrained mobility, unrealized economic growth, and loss of U.S. aviation leadership.

Figure 3



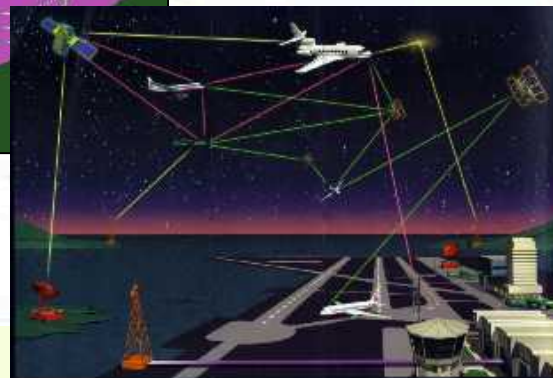
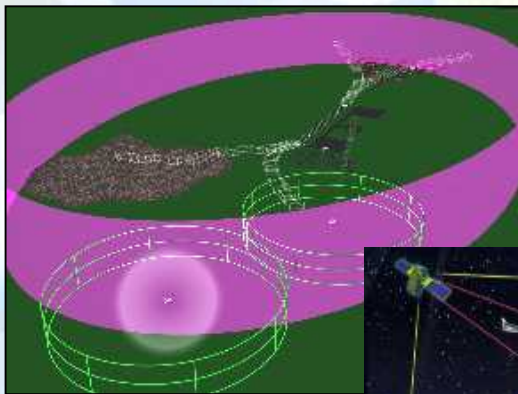
The Difficulty About Predictions...

- 1. “The telephone has too many shortcomings to be seriously considered as a means of communication.”
– Western Union executive, 1876**
- 2. “The problem with television is that the people must sit and keep their eyes glued on a screen; the average American family hasn’t time for it.”
– NY Times, 1939 (World’s Fair)**
- 3. “I think there is a world market for maybe five computers.”
– IBM Chairman Thomas Watson, 1943**
- 4. “Computers in the future may weigh no more than 1.5 tons.”
– Popular Mechanics, 1949**
- 5. “There is no reason for individuals to have a computer in their home.”
- DEC Chairman Ken Olson (DEC), 1977**
- 6. “640,000 bytes of memory ought to be enough for anybody.”
– Microsoft Chief Software Architect Bill Gates, 1981**



Innovations Affecting 21st Century General Aviation Airspace Operations

- **A New Generation of Digital Aircraft**
- **All-Digital Cockpit Systems (PFD+MFD)**
- **Digital Flight Controls**
- **Digital Engine Controls**
- **Airborne-collaborative Sequencing Software**
- **Lower Landing Minima Without ILS**

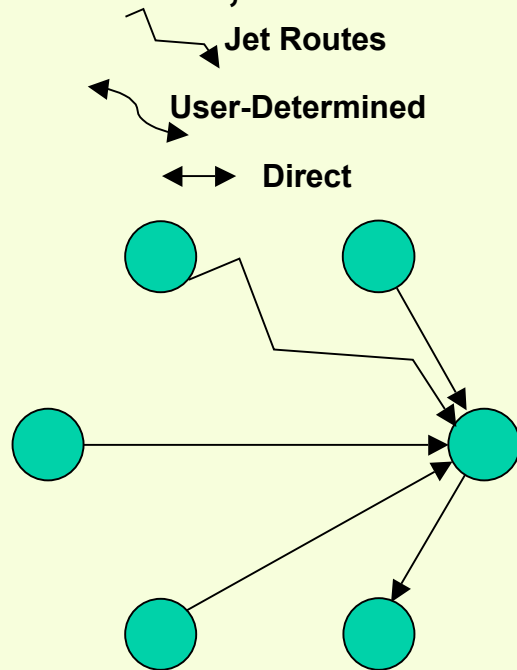


- **Airborne Internet**
- **Digital Airport Information Systems**
- **Digital Airspace Management Systems**
- **ADS-B-based Separation**
- **Non-towered Airports Procedures**
- **Non-radar Operations in IMC**



Topologies for Three Air Transportation Networks (With Unique Business Models)

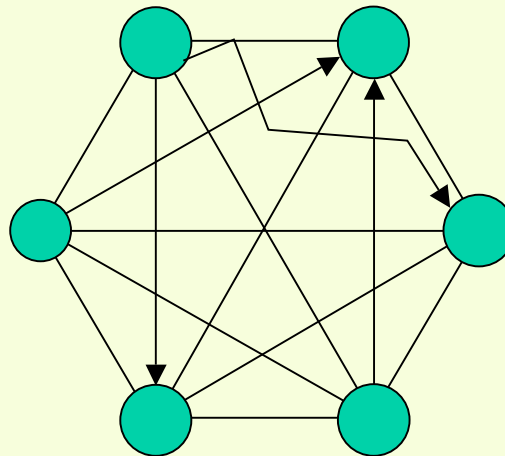
A. Hub-and-Spoke Directed, Scheduled



Nodes (n) = 6
Links (k) = n-1 = 5

For Example:
ORF- ORD:ORD- DEN
RIC - MSP: MSP - GFK
Tier 1,2 Carriers

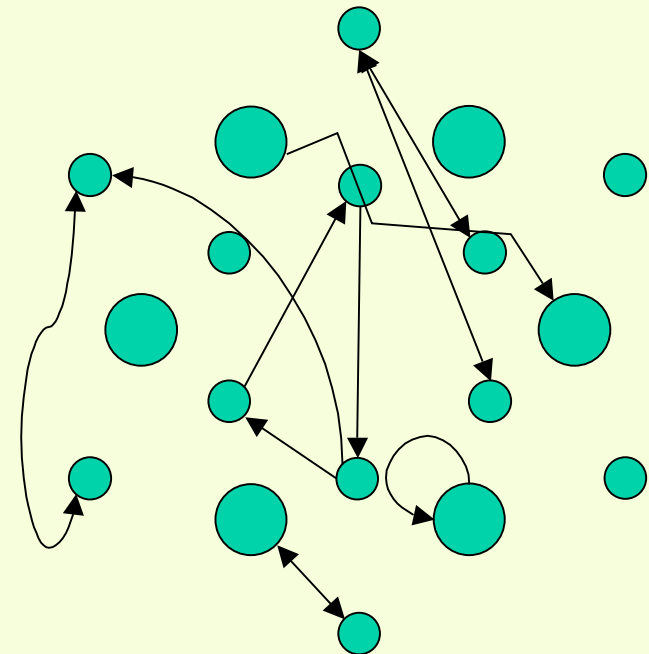
B. Point-to-Point Directed, Scheduled



Nodes (n) = 6
Links (k) = $n(n-1)/2 = 15$

For Example:
ORF- LAS
MDW - NWK
Tier 2,3 Carriers

C. Distributed Undirected, On-Demand



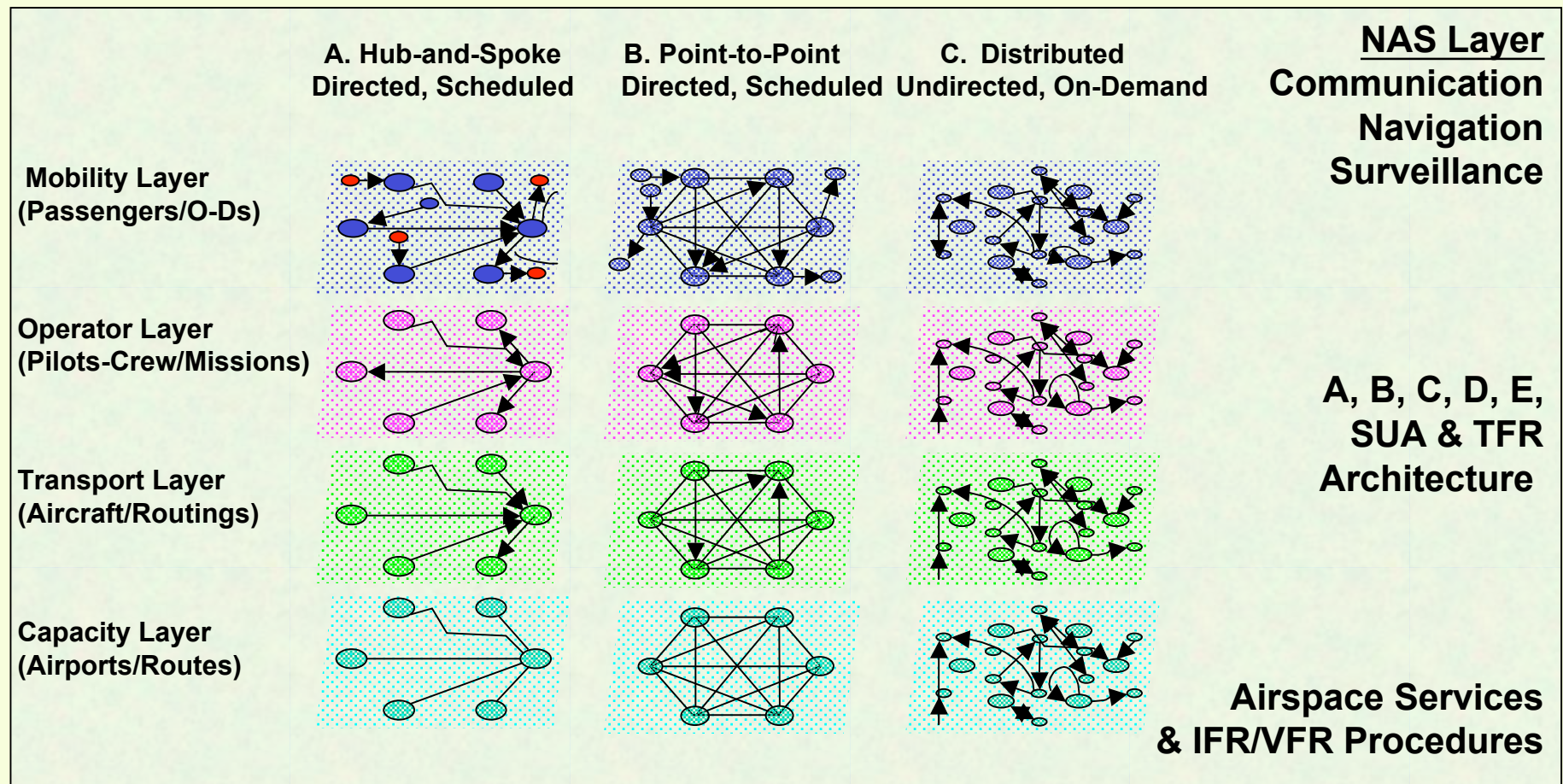
Nodes (n) = 18
Links (k) = $n(n-1)/2 = 153$
(Three times the nodes = 10X links)

Tier 4 Carriers, UAVs, RIAs, PAVs



Topologies for Air Transportation Networks

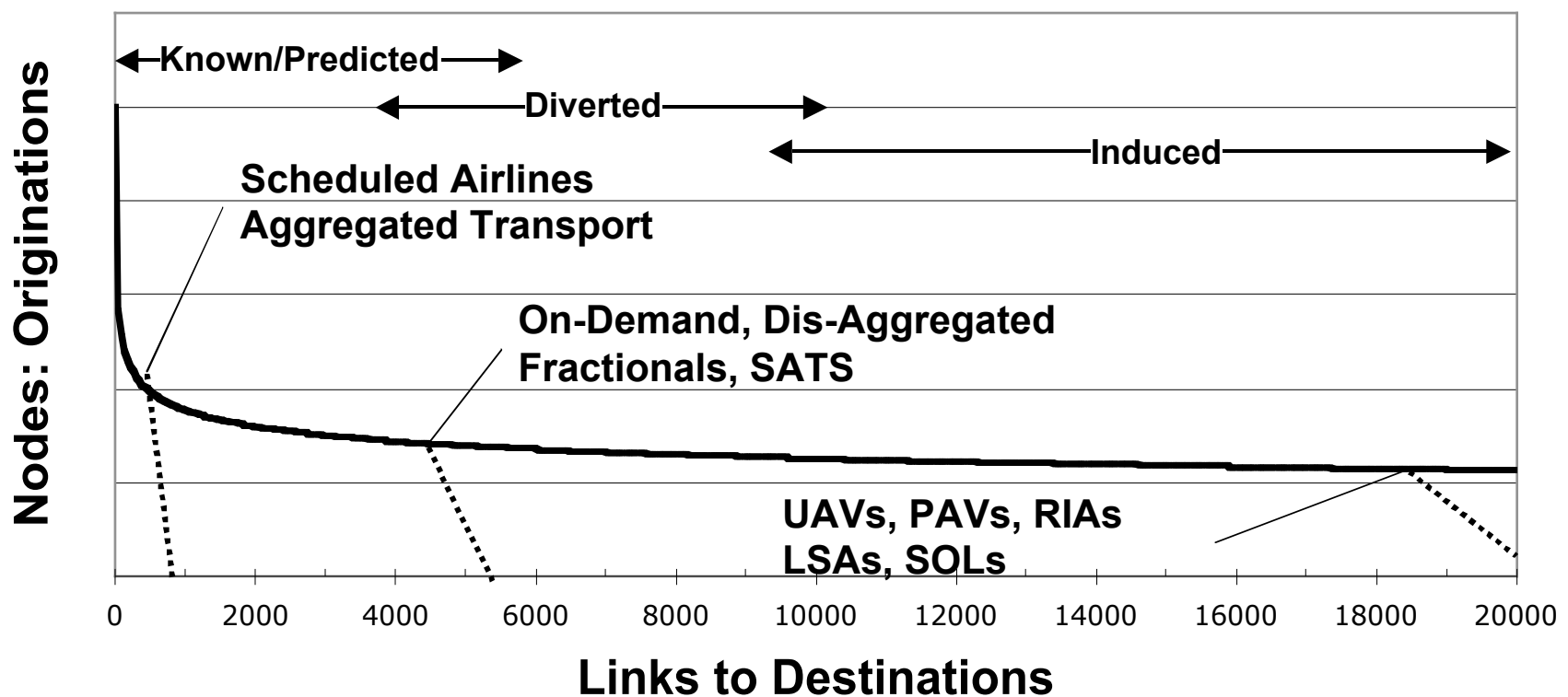
Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?





Small World Distribution in Air Transportation

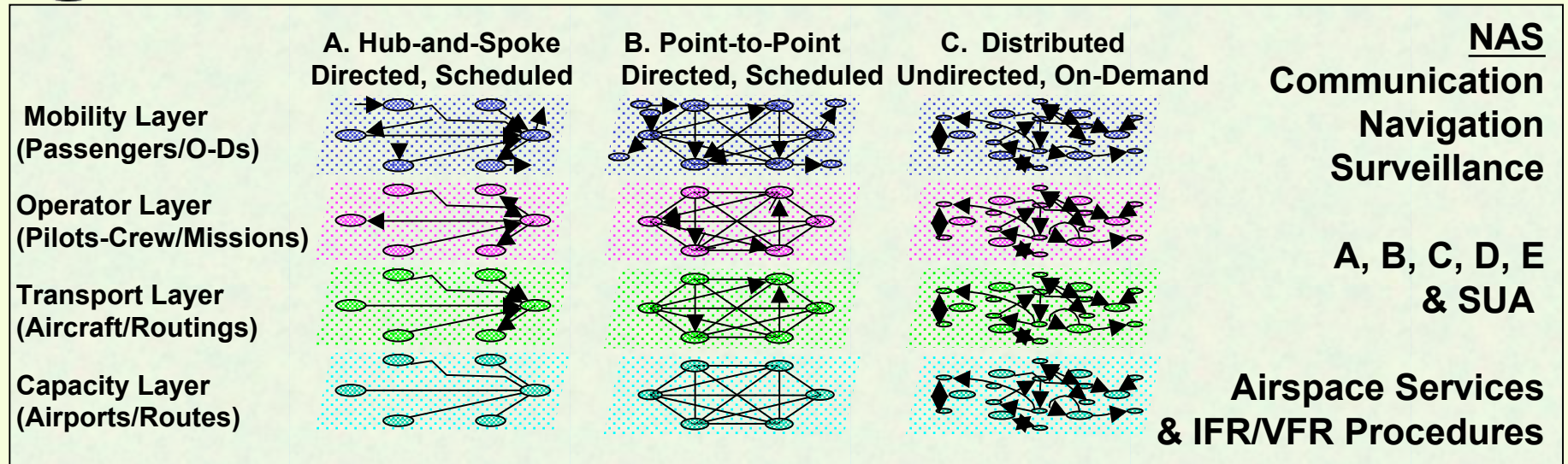
Power Law Distribution in Air Transportation (Mobility & Capacity Layers)



Q: What network characteristics, topologies, and technology strategies would lead to scalable air transportation system behavior?



Possible Topologies for Air Transportation Networks

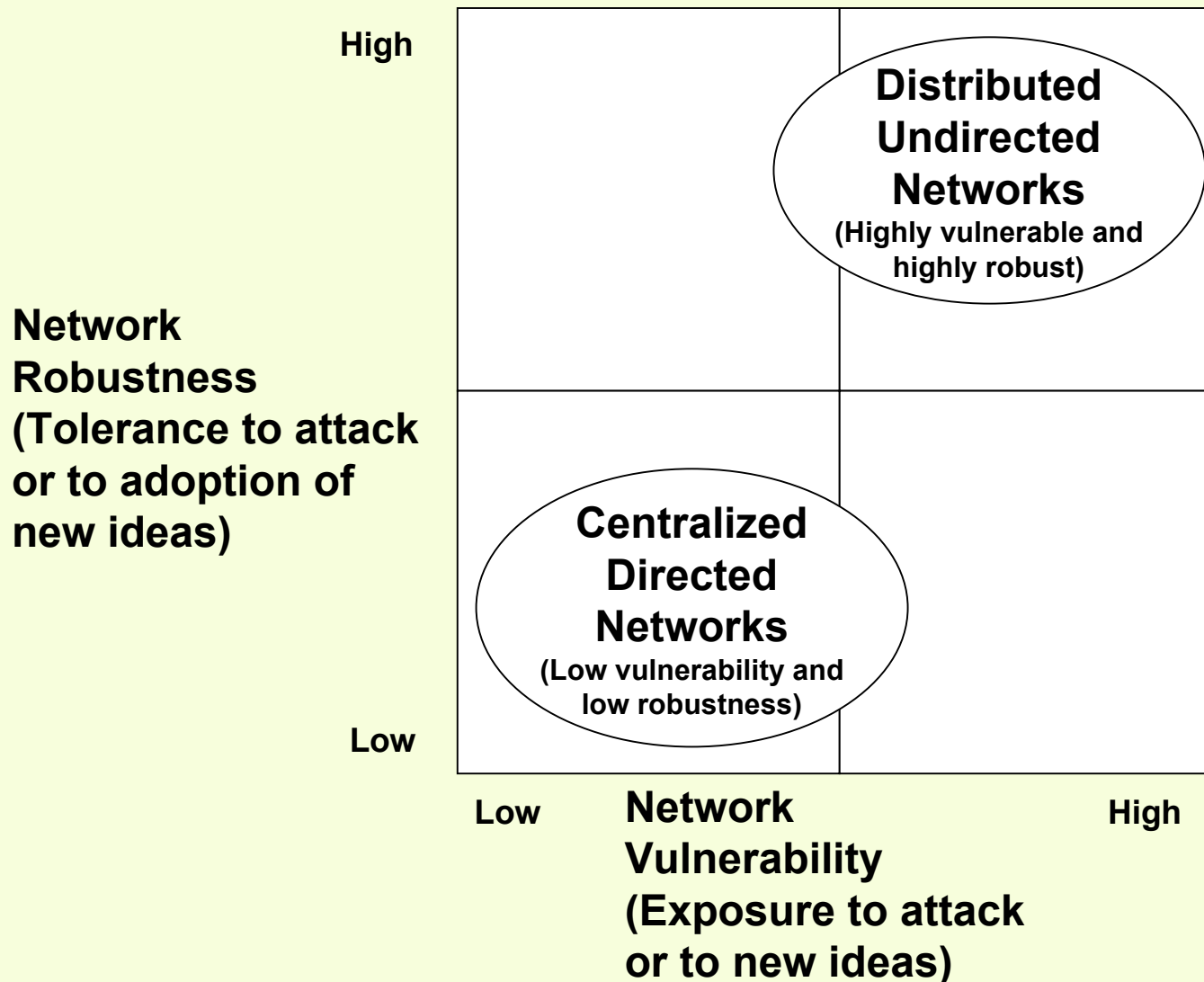


What kinds of questions might be approachable applying the science of networks?

1. What are the comparative mobility metrics (e.g., door-to-door speeds) for networks A, B, and C?
2. What are the optimal sizes, costs, performance of aircraft for these networks?
3. What are the comparative energy consumptions for optimized operations of these networks?
4. What are the comparative noise constraint optimization issues for these networks?
5. What are the comparative infrastructure costs at each layer of these networks?
6. What are the comparative degrees of resistance to disruptions of these networks?
7. What are the comparative degrees of vulnerabilities of these networks?
8. What are the percolation behaviors for “events” in these networks?
9. What changes occur within the network when one of the layers is fundamentally altered?
10. Others...?



Topological Robustness





Scale-Free Networks and Diffusion of Innovations

- Innovation life cycles can follow classic logistics growth patterns (S-Curves), shaped by network behaviors (social, technical, *et.al.*).
- Diffusion of innovations is accelerated by scale-free network behaviors (as contrasted with hierarchical network behaviors)
- If the network contains a percolating vulnerable cluster, then it is possible for global cascades to occur
- Global cascades exhibit self-perpetuating growth, ultimately altering the state of the entire system.

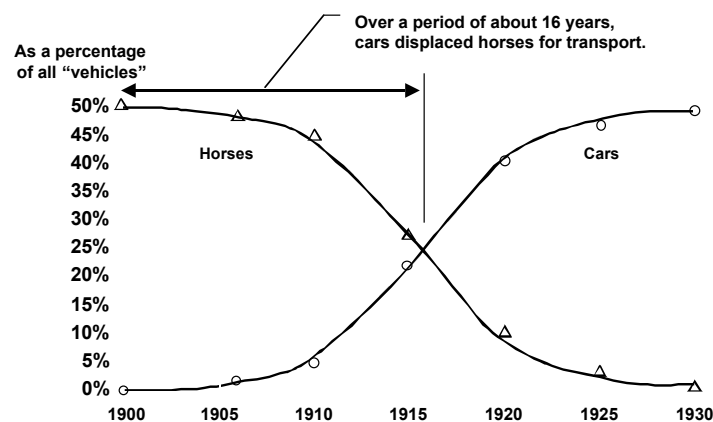


Figure D.- The Substitution of Cars for Horses (N. Nakicenovic, 1986)

Aviation's Future is Driven By Technology

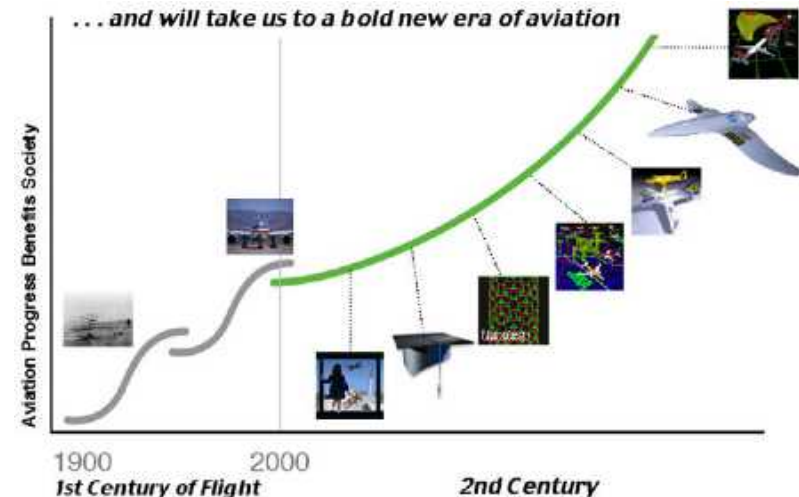


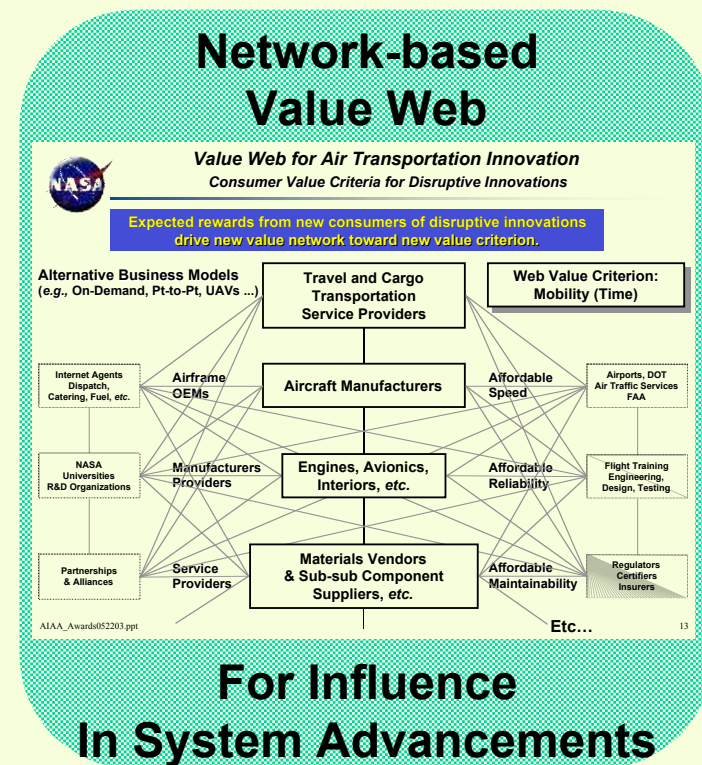
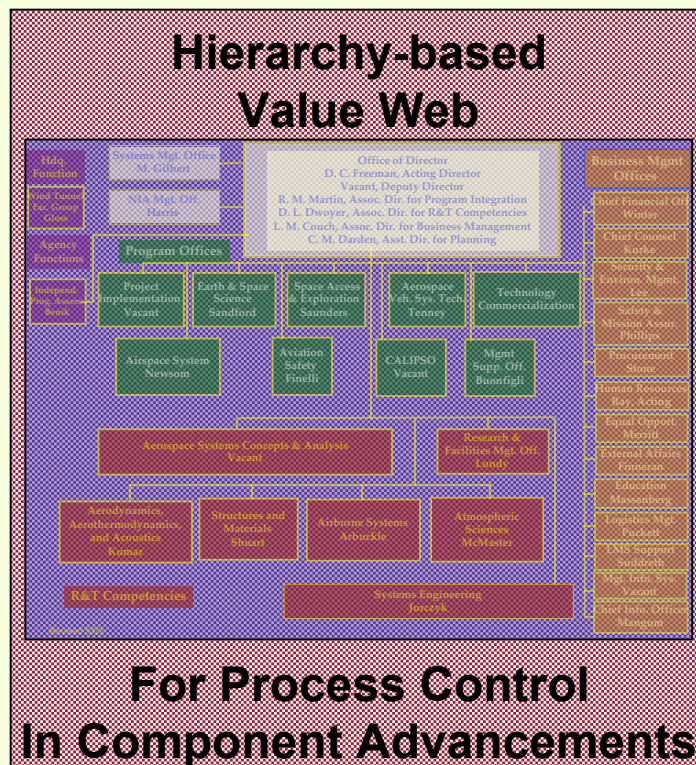
Figure A.- NASA Blueprint for Aeronautics Depicts Innovation Life Cycles, Past and Future



Organizing for Diffusion of Innovations

Rates of diffusion for innovations are functions of:

- Scale free nature of the network (fitness-based growth and power-law relations between links)
- Thresholds of vulnerability to innovation (existence of need)
- Existence of at least one well-connected percolating cluster (incubator for innovation)
- The number of early adopters distributed across the population (potential for growth of links)
- The size of the clusters of early adopters (existence of highly linked groups of adopters)
- The connectivity between the early adopters and the innovators (ability to legitimize the innovation)





Public-Private Consortium Membership



**NATIONAL CONSORTIUM FOR
AVIATION MOBILITY (NCAM)**



What Others Are Saying

Vision For Advanced Personal Air Mobility:

“Enable a safe, secure, affordable, easy-to-use, advanced mode of personal air transportation that expands access to more communities and decreases travel time for a broad segment of the American public.

***Strategic Council for NASA-NCAM Partnership
2003***

[An] “area of focus is improving the capability of local airports. ... get more traffic in and out of small airports more safely. We’ve learned a lot about the needs of these airports through Capstone in Alaska ... and from NASA’s work on the Small Aircraft Transportation System, or SATS, program.”

***FAA Administrator Marion C. Blakey
AIA Conference May 22, 2003***

“The cost of inaction [in aviation advancements] is gridlock, constrained mobility, unrealized economic growth, and loss of U.S. aviation leadership.”

***NASA Blueprint for 21st Century Aeronautics
2002***

“Fast, safe, and secure point-to-point transportation should be available not just between major hub airports, but also between convenient local airports via low-cost, jet air-taxis.”

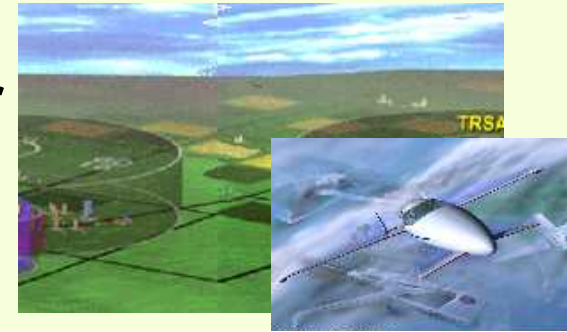
***President’s Commission on the Future of the U.S. Aerospace Industry
2002***



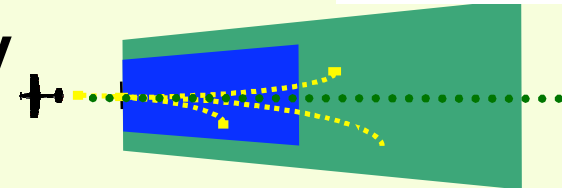
Small Aircraft Transportation System Project

Operating Capabilities for Access to All Communities/

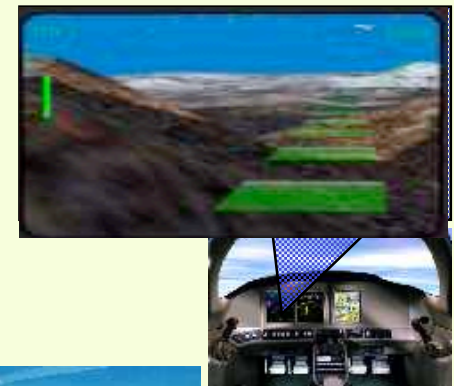
**Higher Volume Operations in Non-Radar
Airspace and at Non-Towered Airports**



**Lower Landing Minimums at Minimally
Equipped Landing Facilities**



**Increase Single-Pilot Crew Safety &
Mission Reliability**

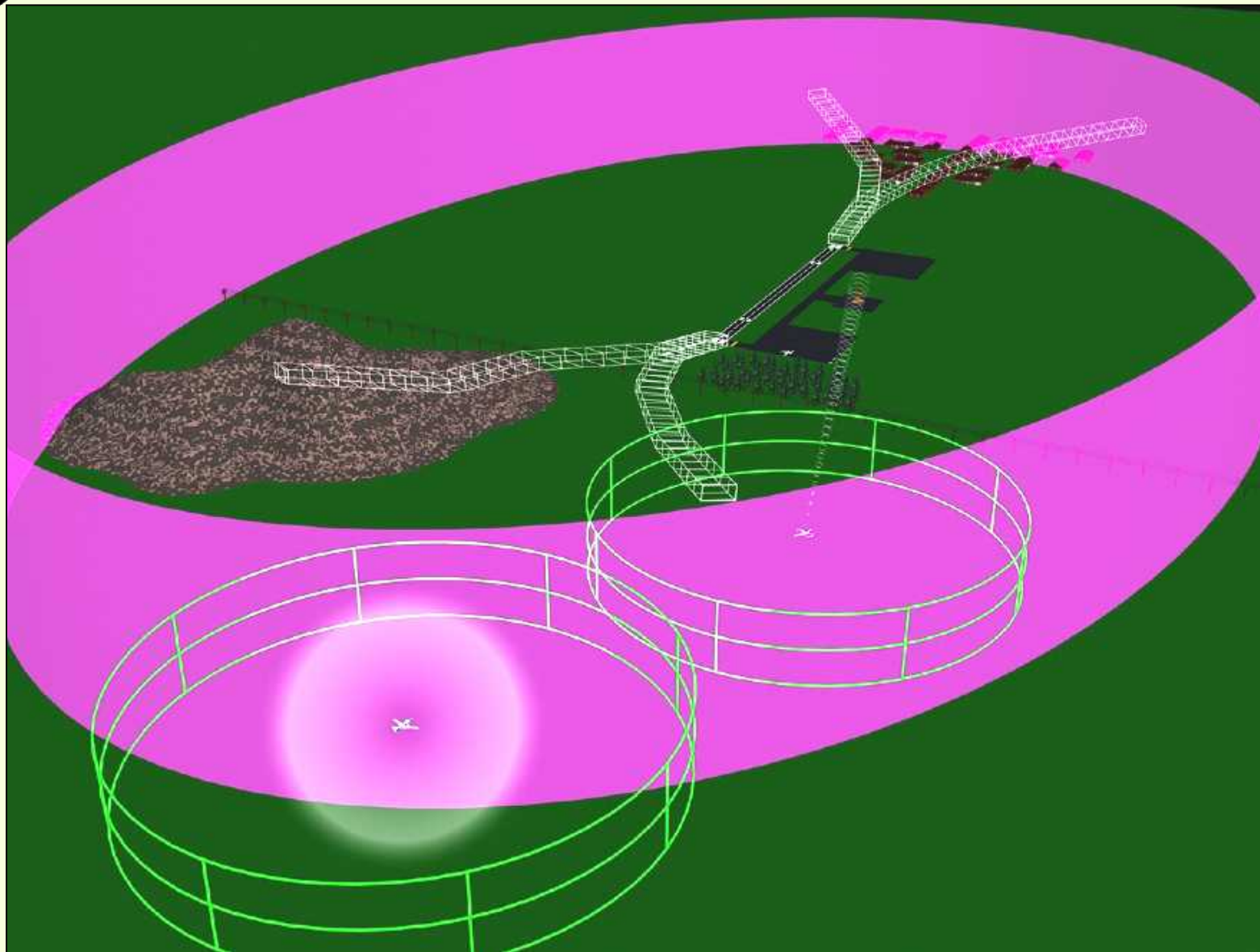


**En Route Procedures & Systems for
Integrated Fleet Operations**





SATS Operating Capabilities

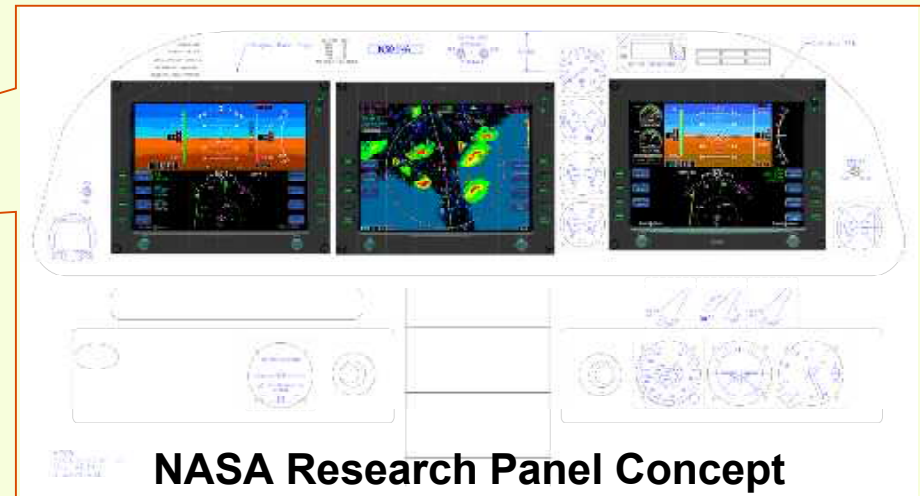






SATS Research Aircraft

NASA 501 Cirrus SR-22X



- **Digital, all-electric cockpit system architecture**
 - Dual avionics computer resources, databus, reversionary displays, and redundant power sources
 - Fully integrated IFR primary flight display (PFD) and multi-function display (MFD)
 - Digital radios / datalink for ADS-B, FIS-B, CPDLC, D-ATIS, AMM-Comm
 - GPS / DGPS / RNP RNAV
 - Synthetic vision-based terrain & obstacle graphics
 - Intuitive flight path guidance
- **Research Software Development**
 - Self-Separation: Conflict Alerting and Conflict Prevention Graphics (ASI, VSI, Nav-Hdg)
 - Sequencing software and graphics (Requested Time of Arrival - RTA waypoints)
 - Self-Controlled Airspace “Rules of the Road”



Airborne Internet Preliminary Demonstration

Accomplishment

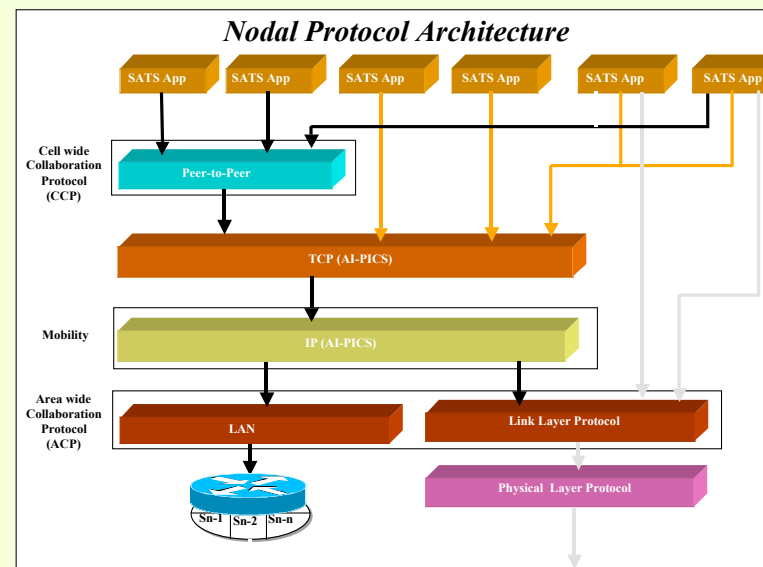
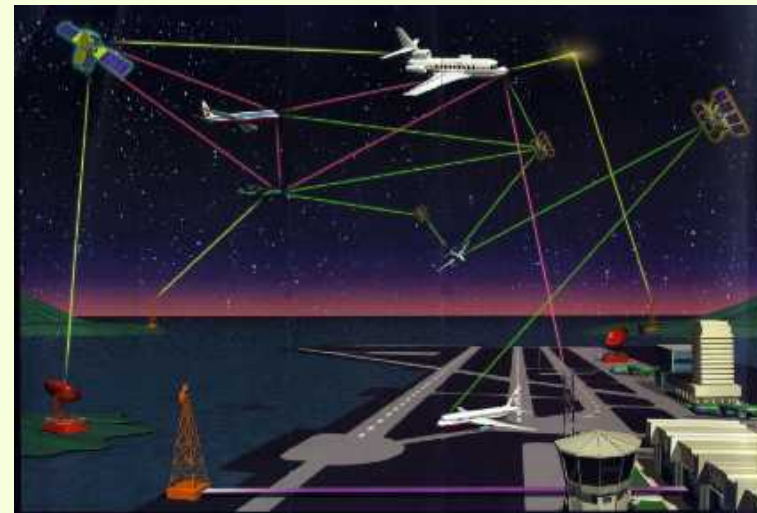
Demonstrated integrated communications, navigation, and surveillance architecture in lab testbed

Benefits

- Mobile and policy-based routing
- Service priority communications
- Secure network communications
- Point-to-point, point-to-multipoint, and broadcast addressing
- Based on open standards and protocols.
- Minimizes number of radios and antennas on an aircraft—goal is single radio for all data communications

Plans

- Evaluate candidate communication architectures
- Plan flight evaluations in 2005
- Airborne Internet Consortium Development



GLENN RESEARCH CENTER



FAA Roles

Small Community Airports Initiative

- CNS Infrastructure

Safe Flight 21

- Capstone

AVR-SATS Team

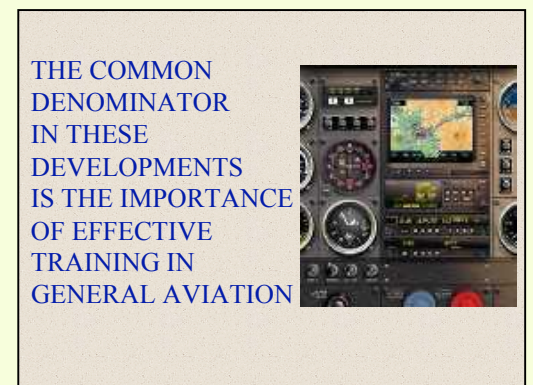
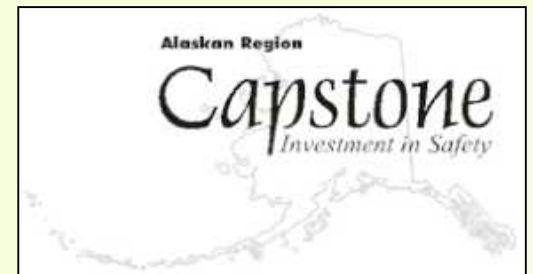
- Certification Issues

Flight Standards Services

- Flight Training Technologies
- RNP-based Operations

FAA Technical Center:

- Airborne Internet
- Advanced procedures simulations





Reducing the Cost of Speed

Cirrus



Lancair



Cessna Mustang



**Enabling
New Business Models
For Air Mobility**

Eclipse



**Honda,
Toyota,
And others...**

Adam Aircraft



Safire



Diamond

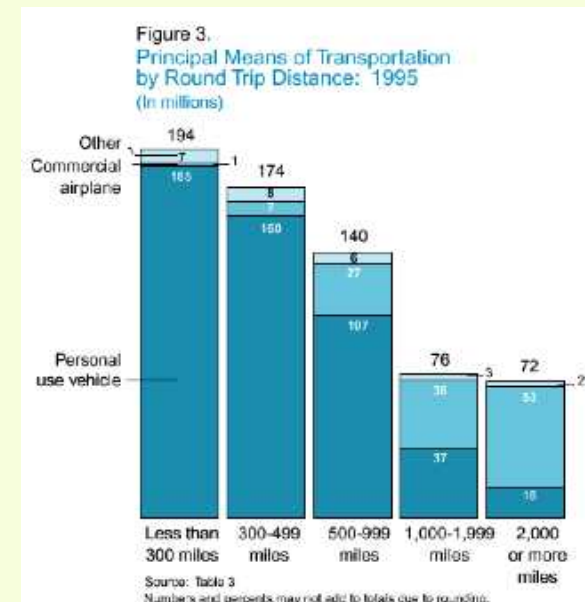




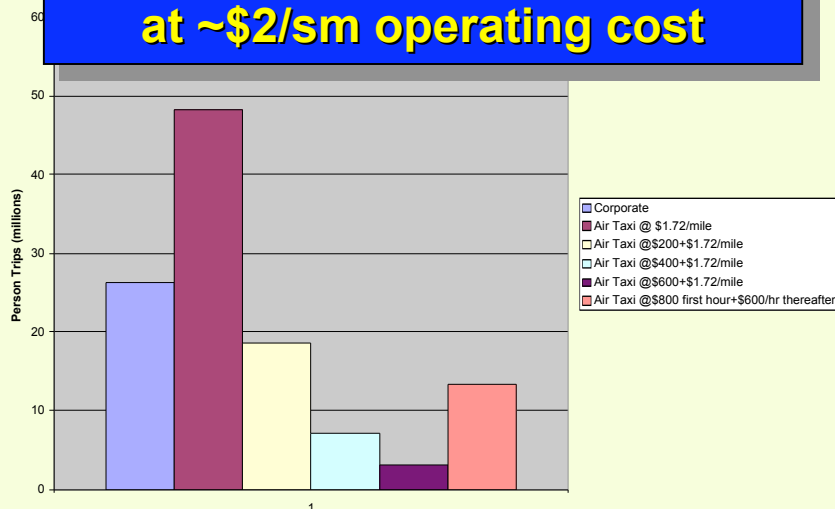
Future Aircraft Market

Diverted Demand and Sensitivity Assessments

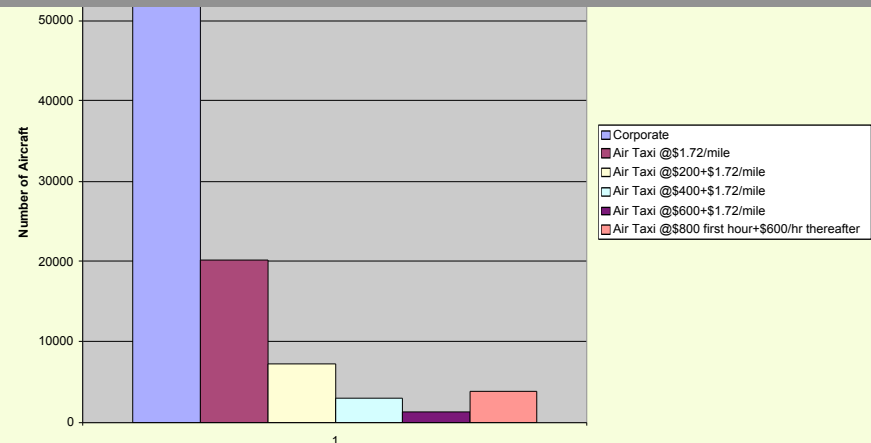
- Approach - Predict diverted mode choice at National level between automobile, scheduled air, and on-demand air travel based on the value of a traveler's time and the cost of the trip (NASA CR 2002-211927).
 - Data Source - 1995 American Travel Survey + 2000 US Census
 - Tools - Integrated Air Transportation System Evaluation Tool (IATSET), macro economic model



Between 13 and 47 million trips at ~\$2/sm operating cost



Between 7,000 and 52,000 aircraft required to serve new markets





North Carolina Market Assessment For Diverted (On-Demand) Business Travel



Hub Communities: 25 Counties - 52% Population
On-Demand Market: 75 Counties - 48% Population

Assumptions

- **Business Travel (no personal travel)**
- **98% Accommodation @ ≤ 3 hours**
- **\$1.85 per passenger ticket mile**
- **No weather impacts assessed**

Research Triangle Institute (2002). *North Carolina fourth-tier air transportation market analysis*. NCDOT Contract No. A304132: NC DOT Division of Aviation market Analysis for the Small Aircraft Transportation System (SATS) in North Carolina.

Findings:

**175 fleet of next generation jets required to serve
425 passengers/day demand
at \$1.85 per passenger-seat mile**

- **Demand highest in communities most remote from commercial air service**
- **Air-taxi service best meets needs of surveyed likely business travelers**
- **Increased passenger volume allows higher profit margins and/or lower ticket prices and shorter accommodation intervals**
- **Advanced technology significantly reduces required ticket price**

* Ignores potential passenger demand from “hub communities”, ignores passenger travel originating external to NC, ignores leisure and vacation travel demand, uses simplified dispatch strategy with no “optimization”



Summary

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**SATS Concept Supports 21st Century Mobility Needs
A Public-Private Partnership Enables System Innovation
Florida hosts industry entrepreneurs and early adopter markets**



Epilogue



***From the sands of
Kill Devil Hill***

***To
“Anywhere, Anytime,
Anyone, Anyplace”
(The Report of the Aerospace
Commission, 2002)***



**From Wheels on America
to Wings on America**



**Equitable
On-Demand
Widely Distributed
Point-to-Any Point
21st Century Air Mobility**